APPLICATION FOR PATENT

INVENTORS: **NEIL H. AKKERMAN; DANIEL O. DEWEY**

TITLE: **SYSTEM FOR MOUNTING AN ENGINE TO A FRAME**

SPECIFICATION

Field of the Invention

This invention relates to an improved system for mounting an engine to a frame in a manner to measure torque while accommodating frame misalignment and flexure due to working loads. More particularly, it relates to such a system which is insensitive to most movement-induced acceleration forces. In this context, the engine is a rigid assembly including the motor and/or transmission and/or differential gear box that generates the driving torque so as, for example, to move a vehicle.

Background of the Invention

It is common to mount a reciprocating engine with resilient mounting assemblies to isolate the frame from engine vibration. Another not often mentioned benefit of resilient mounting is the accommodation of manufacturing tolerances when mating two relatively rigid assemblies such as an engine and automobile frame. Furthermore, resilient mounting accommodates flexure of the frame caused by the engine working torque and vehicle dynamics. Vehicle dynamics includes stresses and strains caused by movement over uneven road surfaces, acceleration forces to increase velocity, braking forces to slow the vehicle, and forces generated when going around corners.

E.B. Etchells in U.S. Pat. No. 2,953,336 teaches the common three point resilient mounting of an engine transmission assembly into an automobile frame. This patent

includes discussion of the nodal positioning of the engine mounts to minimize vibrations while controlling engine torque and accommodating road induced vibrations. This system incorporates a single resilient mounting at the rear of the engine assembly and a pair of transversely spaced resilient mounts at the front of the engine. The nodal point is a place of minimum vibration. Positioning of the front engine mounts as close as is practical to the percussion points of the engine assembly reduces road induced loads on the rear mount and allows the rear mount to be soft and compliant.

The mounting system of *Etchells* is widely utilized and there exist improvement patents such as *Fehlberg*, U.S. Pat. No. 3,731,896, that demonstrates continued applicability. *Fehlberg* teaches the need for mechanical limits to retain the engine transmission assembly to the frame when the strength limits of resilient elastic elements are exceeded.

R. E. Krueger, in U.S. Pat. No. 3,146,986, discusses the need for torque measurement in automobiles, boats and small airplanes. The embodiment shown includes hydraulic sensing means for measuring torque, and is mounted parallel to a resilient elastic engine mount in an automobile.

The engine in an automobile is heavy, generates significant torque and must be firmly attached to the frame to resist road dynamics. These considerations require that the resilient elastic mount be of sufficient stiffness to prohibit excessive engine movements. Mounting a sensor in parallel to the resilient mount induces measurement error caused by frame deflection, thermal expansion or contraction of the elastic element and temperature induced elastic stiffness changes. The zero adjusting unit provided in the *Krueger* apparatus can only be effective if all conditions are static after adjustment

and during the time measurements are taken. Repeatability and accuracy are affected when measurements are taken in parallel to the engine retention components of the engine mount.

G. L. Malchow, in U.S. Pat. No. 3,903,738, discloses a torque-sensing device that replaces one of the engine mounts in an engine installation as depicted in *Etchells*. *Malchow* removes one of the resilient mounts and replaces it with a strain gage-equipped pivotal yoke assembly. In this configuration, the engine is restrained from rotational movement by a force couple applied on one side by the elastic engine mount and on the other side by the strain gage-equipped pivotal yoke assembly. The configuration of the yoke assembly of the strain gage equipped engine mount makes determination of the length of moment arm and the magnitude of restraining force a complex geometrical problem. *Malchow* avoids these issues by calibrating the apparatus "where weights were suspended from a torque arm which was connected to the transmission out put shaft."

The stability of the complex geometry that determines torque arm length affects calibration and repeatability of the torque measurement. The location of the restraining force through the resilient elastic mount is subject to movement-induced creep or sag. Resilient elastic supports undergo creep and sag over time due to thermal and long term loading. Also, frame flexure due to road induced loads can cause lateral displacements between the frame mounting points of the front engine mounts, changing the inclination of the yoke, and significantly altering the calibration of torque measurement.

The yoke assembly does not restrain the engine from movement due to acceleration loads caused by braking or acceleration. These loads are restrained by the resilient engine mount on the side opposite the yoke assembly and the compliant mount

on the transmission. Aside from potential safety issues, the resilient engine mounts will allow movement that may result in damage to the yoke assembly and/or inaccurate torque measurement.

A three point mounting system, with a sensor at one of the mounting points, has an effective pivotal axis through the other two mounting points. The center of gravity of the engine mass is significantly displaced both vertically and laterally from the pivotal axis of the engine, thereby departing from the teachings of *Etchells* regarding the importance of nodal positioning of the mounts.

Even when vehicle velocity and engine torque are constant, the lateral or sideways displacement of the center of gravity with respect to the pivotal axis allows vertical accelerations of the vehicle, such as those caused by movement while traveling over bumps in the road, to create forces that result in false torque measurements.

Similarly, even when vehicle velocity and engine torque are constant, vertical displacement of the center of gravity from the pivotal axis allows cornering accelerations caused by the vehicle going around turns to create forces that result in false torque measurements.

Also, even if engine torque is constant, combined vertical and lateral displacement of the center of gravity from the pivotal axis along with an inclined pivotal axis allows longitudinal accelerations resulting in vehicle velocity changes to create forces that result in false torque measurements.

Summary of the Invention

Accordingly, it is a principal object of the present invention to provide an improved system for mounting an engine to a frame in a manner to measure engine torque while isolating the measurement from loads induced by installation misalignments and frame deflections as well as acceleration induced forces.

Another object is to provide a mounting system which is compatible with previously installed resilient engine mounts, without engine or frame modifications.

A further object is to provide such a system wherein torque is sensed by a transducer which has the ability to sense torque in only one or in both directions.

These and other objects are accomplished in accordance with illustrated embodiments of the invention wherein the system includes: first and second bearings, each connectable to the frame and engine to form a pivotal axis about which the engine is free to rotate relative to the frame, wherein, in accordance with the objects of the invention, the pivotal axis passes near the center of gravity of the engine and is aligned other than orthogonally to the axis of the engine output shaft. More particularly, the system also includes a load sensing transducer which includes parts connectable to the frame and the engine for resisting and measuring rotational forces between the engine and the frame about the pivotal axis.

In one embodiment of the invention, the first and second bearings are connectable to portions of the frame and engine and are in axial alignment to receive shaft portions on the pivotal axis displaced from one another about the engine.

In other embodiments, one of the bearings comprises bearing segments, with each segment having a first part guidably moveable with respect to a second part, forming an

instantaneous pivotal center on the pivotal axis. The other bearing preferably comprises a compliant engine mount. For reasons which will be apparent from the description to follow, the pivotal axis extends through or near the center of gravity of the engine.

Brief Description of the Drawings

These and other objects of the present invention are accomplished as described in the following description and drawings in which:

FIG. 1 is a side view of an engine mounted on a frame in accordance with one embodiment of the invention.

FIG. 1(a) is a top view of the engine and frame shown in FIG. 1, as seen from 1(a) – 1(a) of FIG. 1.

FIG. 1(b) is a rear view of the engine shown in FIG. 1, as seen from 1(b) – 1(b) of FIG. 1.

FIG. 1(c) is a sectional view of the engine shown in FIG. 1, as seen along 1(c) – 1(c) of FIG. 1.

FIG. 1(d) is an enlarged detail view of a portion of FIG. 1, as shown thereupon.

FIG. 2 is a side view of an engine mounted in accordance with another embodiment of the invention.

FIG. 2(a) is a rear view of the engine shown in FIG. 2, as seen from 2(a) – 2(a) of FIG. 2.

FIG. 2(b) is a cross-sectional view of the engine and frame shown in FIG. 2, taken along the line 2(b) – 2(b) of FIG. 2, and broken away to show the rear bearing.

FIG. 3 is an enlarged rear view of a bearing segment shown in FIG. 2(a).

FIG. 3(a) is a view of the bearing segment shown in FIG. 3, as seen along the line 3(a) – 3(a) of FIG. 3.

FIG. 3(b) is a cross-sectional view of the bearing segment shown in FIG. 3, as seen along the line 3(b) – 3(b) of FIG. 3.

FIG. 3(c) is a cross-sectional view of the bearing segment shown in FIG. 3, as seen along the line 3(c) – 3(c) of FIG. 3.

FIG. 3(d) is a cross-sectional view of the bearing segment shown in FIG. 3(a), as seen along the line 3(d) – 3(d) of FIG. 3(a).

FIG. 3(e) is an exploded view showing the parts comprising the bearing segment shown in FIG. 3.

FIG. 4 is an enlarged rear view of a bearing segment shown in FIG. 2(a).

FIG. 4(a) is a view of the bearing segment shown in FIG. 4, as seen along the line 4(a) – 4(a) of FIG. 4.

FIG. 4(b) is a cross-sectional view of the bearing segment shown in FIG. 4, as seen along the line 4(b) – 4(b) of FIG. 4.

FIG. 4(c) is a cross-sectional view of the bearing segment shown in FIG. 4, as seen along the line 4(c) – 4(c) of FIG. 4.

FIG. 4(d) is a cross-sectional view of the bearing segment shown in FIG. 4(a), as seen along the line 4(d) – 4(d) of FIG. 4(a).

FIG. 5 is a side view of an engine mounted on a frame in accordance with a further embodiment of the invention.

FIG. 5(a) is a rear view of the engine and frame shown in FIG. 5.

FIG. 5(b) is an enlarged cross-sectional view of the engine and frame shown in FIG. 5, as seen along the line 5(b) – 5(b) of FIG. 5 and broken away to show the rear bearing.

FIG. 6 is an expanded rear view of a bearing segment shown in FIG. 5(a).

FIG. 6(a) is a cross-sectional view of the bearing segment shown in FIG. 6, as seen along the line 6(a) – 6(a) of FIG. 6.

FIG. 6(b) is a cross-sectional view of the bearing segment shown in FIG. 6, as seen along the line 6(b) – 6(b) of FIG. 6.

FIG. 6(c) is a cross-sectional view of the bearing segment shown in FIG. 6, as seen along the line 6(c) – 6(c) of FIG. 6.

FIG. 6(d) is a cross-sectional view of the bearing segment shown in FIG. 6(a), as seen along the line 6(d) – 6(d) of FIG. 6(a).

FIG. 7 is a side elevation view of an engine mounted in accordance with a further embodiment of the invention.

FIG. 7(a) is an enlarged rear view of the engine shown in FIG. 7, as seen along 7(a) – 7(a) of FIG. 7.

FIG. 7(b) is a cross-sectional view of the engine shown in FIG. 7, as seen along the line 7(b) – 7(b) of FIG. 7, and broken away in part to show the rear bearing.

FIG. 8 is an enlarged rear view of a bearing segment shown in FIG. 7(a).

FIG. 8(a) is a cross-sectional view of the bearing segment shown in FIG. 8, as seen along the line 8(a) – 8(a) of FIG. 8.

FIG. 8(b) is a cross-sectional view of the bearing segment shown in FIG. 8, as seen along the line 8(b) – 8(b) of FIG. 8.

FIG. 8(c) is a cross-sectional view of the bearing segment shown in FIG. 8, as seen along the line 8(c) – 8(c) of FIG. 8.

FIG. 8(d) is a cross-sectional view of the bearing segment shown in FIG. 8(a), as seen along the line 8(d) – 8(d) of FIG. 8(a).

FIG. 8(e) is an exploded view showing the parts comprising the bearing segment shown in FIG. 8.

FIG. 9 is a rear view of a bearing segment shown in FIG. 7(a)

FIG. 9(a) is a cross-sectional view of the bearing segment shown in FIG. 9, as seen along the line 9(a) – 9(a) of FIG. 9.

FIG. 9(b) is a cross-sectional view of the bearing segment shown in FIG. 9, as seen along the line 9(b) – 9(b) of FIG. 9.

FIG. 9(c) is a cross-sectional view of the bearing segment shown in FIG. 9, as seen along the line 9(c) – 9(c) of FIG. 9.

FIG. 9(d) is a cross-sectional view of the bearing segment shown in FIG. 9(a), as seen along the line 9(d) – 9(d) of FIG. 9(a).

<u>Detailed Description of the Preferred Embodiments</u>

A first embodiment of the invention is shown in FIGS. 1 and 1(a). An engine **1** generally consists of internal combustion motor **2** and transmission assembly **3** as might be installed in any common automobile. The engine **1** is secured to the automobile frame **8** (partially shown) by bearings **4** and **5**, which receive rigid extensions **6** and **6a** of the engine **1**, and which are pillow block bearings as are commonly known to the art, as, for example, Model No. G1105KRAB, manufactured by Torrington Company, a division of

Ingersoll-Rand. Bolts **7** fasten the bearings **4** and **5** to the automobile frame **8**. Bearings **4** and **5** are fitted to rigid extensions **6** and **6(a)** of the engine. Stop collar **10** is located on shaft extension **6(a)** to prevent fore and aft movement of the engine **1** in relation to the frame **8**.

Bearings **4** and **5** form a pivotal axis **9** about which the mass of the engine may rotate. As will be discussed more fully below, pivotal axis **9** passes through or near the center of gravity **CG** of the engine **1**. A lug **11** projects outwardly from the engine **1**, and a load-sensing transducer **12** is connected between lug **11** and the automobile frame **8**, as shown, for example, in U.S. Pat. No. 3,903,738, for measuring tension generated by the engine and transmitted to its output shaft **13**.

Thus, it can be seen that the engine **1** is securely attached to the frame in that bearings **4** and **5**, and stop collar **10** provide vertical, lateral and longitudinal support of the engine mass and define pivotal axis **9**. Torque generated by the engine **1** and transmitted to the output shaft **13**, creates a reaction torque that is restrained by the load-sensing transducer **12** and lug **11**.

Load-sensing transducer **12** may be any suitable type known to the art, such as Model DSM Series transducers manufactured by Transducer Techniques of Rio Nedo, Temecula, Ca. The transducer **12** may be positioned in any convenient location radially displaced from the pivotal axis of the engine **1**, as long as its axis of sensitivity, x on FIG. 1, is so oriented as to measure the torque. Since the transducer **12** does not form a part of, and is in fact independent of, the means by which the engine is retained to the frame, it may be easily repaired or replaced.

Thus, for example, the angle **beta**, which is the angle between the axis of rotation of the engine output shaft **13** and the pivotal axis **9**, projected onto and measured on a mutually parallel plane to both the pivotal axis **9** and axis of rotation of the output shaft **13**, can have any value other than ninety degrees. If angle **beta** had a value of ninety degrees, the bearings **4** and **5** would resist the reaction torque created as a result of engine torque transmitted by the output shaft **13** and the load-sensing transducer **12** would not sense a load in proportion to the engine torque.

The axis of sensitivity x is defined as the axis of the resultant force vector acting on the point of contact on the engine measured by load sensing transducer **12**, and cannot share any plane with the pivotal axis. If x did share a plane with the pivotal axis, the load-sensing transducer **12** would not sense a load in proportion to the engine torque.

As mentioned previously, the center of gravity **CG** of the engine **1** is on or near pivotal axis **9**. When the center of gravity **CG** is positioned exactly on pivotal axis **9**, all engine retention loads except torque are provided by the bearings **4** and **5**, and stop collar **10**, so that the load on the load-sensing transducer **12** is purely a function of engine torque.

If the center of gravity **CG** is displaced laterally of the pivotal axis **9**, a static torque will be measured by the load-sensing transducer **12** proportional to the weight of the engine **1** and the lateral displacement of the center of gravity **CG** from pivotal axis **9**. This static load could be removed by zero offset calibration of the load-sensing transducer **12**. However, if the automobile is moving and passes over bumps in the road or is traveling uphill or downhill, acceleration-induced forces will be generated. These

forces are dynamic, not easily cancelled and thus would represent errors in engine torque measurement.

As shown in FIG. 1, pivotal axis **9** extends at an angle to the horizontal. This angle is a result of typical automobile configuration of low output shafts on the transmission and heavy engines with elevated centers of gravity. This angle is common even in front wheel drive automobiles with transversely mounted engines. The lateral displacement of the **CG** as discussed above would also result in acceleration induced loads on the load-sensing transducer **12** during braking and speed increases. These forces also are dynamic, not easily cancelled, and thus would also represent errors in engine torque measurement. Similarly, if the **CG** was vertically displaced from axis **9**, the load-sensing transducer **12** would experience dynamic loads induced by cornering acceleration.

Although the engine torque measurement will be most accurate if pivotal axis **9** passes directly through the **CG** as shown in FIGS 1 and 1(a), the present invention contemplates that pivotal axis **9** passes sufficiently near the **CG** as to accomplish the accuracy required in torque measurement and the acceleration envelope in which the vehicle will operate while taking measurements. Thus, a family sedan driven on smooth freeways rarely experiences more than one tenth of gravity acceleration and if the torque information is used to determine transmission shift points, perhaps 10% measurement accuracy is adequate. However, a race car running on a rough dirt oval track will be subjected to one times the acceleration of gravity and will probably require 1% measurement accuracy to better tune the engine.

By way of example:

$$F = W \times A / 32.2 \text{ fps}^2$$

Where:

F = force in pounds

A = acceleration in feet per second squared

W = engine weight in pounds

$$Lm = T\% \times Tm \times 12 / (F \times 100)$$

Where:

Lm = length of mislocation in inches

T% = percentage of torque measurement accuracy

Tm = torque output of the motor in pound feet

F = force in pounds

For the purposes of these examples, assume that the engine of both the family sedan and the race car is a 350 cubic inch motor and transmission weighing 750 pounds. The motor has a maximum torque output of 350 pound feet. In the case of the family sedan, $F = 750 \text{ lb} \times 3.22 \text{ fps}^2 / 32.2 \text{ fps}^2 = 75 \text{ lb}$. For a desired torque measurement accuracy of 10%, Lm = 10% x 350 lb-ft x 12 / (75 lb x 100) = 5.6 inches. Therefore, in order to achieve a 10% torque measurement accuracy in the family sedan which experiences a one tenth of one gravity cornering acceleration, pivotal axis **9** must pass within 5.6 inches of the engine **CG**.

In the case of the race car, F = 750 lb x 32.2 fps^2 / 32.2 fps^2 = 750 lb. For a desired torque measurement accuracy of 1%, Lm = 1% x 350 lb-ft x 12 / (750 lb x 100) = 0.056 inches. Therefore, in order to achieve a 1% torque measurement accuracy in the race car which experiences one gravity cornering acceleration, pivotal axis **9** must pass within 0.056 inches of the engine **CG**.

The examples discussed above are, of course, intended only as examples, and should not be understood as limiting the invention, and there are many different vehicles operated under different conditions in which the invention disclosed herein could be adapted with minor variations by a person of ordinary skill in the art. To determine an acceptable location of the pivotal axis relative to the engine **CG**, the specific application should be considered together with the calculations. For instance, a drag race car only races in straight lines on smooth surfaces and would not require accurate location of the pivotal axis relative to the **CG** to eliminate cornering acceleration forces.

Quite often, the pivotal axis is near enough to the **CG** when the **CG** is within the volume defined by the conical shaped space formed by the center of one bearing and the circle defined by the surfaces of relative motion of the other bearing.

In the following alternate embodiment of the invention, the engine restraints are compatible with a three point mounting system similar to that disclosed in *Etchells*, U.S. Pat. No. 2,953,336. Thus, as will be discussed in greater detail below, bearing **5** of FIG. 1 becomes a compliant rubber mount, while bearing **4** of FIG. 1 becomes segmented and compatible with the standard pair of forward engine mounts well known in the art. Together, the two bearings, one being segmented, constrain the engine from movement

with respect to the vehicle frame, except for the small amount of rotation about a pivotal axis which enables torque measurement.

Thus, as shown in FIGS. 2, 2(a), and 2(b), another embodiment of the invention comprises an engine **14** including internal combustion motor **15** and transmission assembly **16** as might be installed in any common automobile. As will be explained, the engine mounting system according to this embodiment of the invention provides the same separation of engine retention forces from torque force measurement as provided by the previously described embodiment shown in FIGS. 1 and 1(a), but has the further advantage of being compatible with the three point engine mounting systems widely used by many automobile manufacturers.

As in the first embodiment, pivotal axis **17** passes through or at least near the center of gravity **CG** of the engine **14**. Near the transmission output shaft **18** is a compliant rubber engine mount **19** as in U.S. Pat. No. 2,953,336, which acts as a bearing in that it positions one end of the pivotal axis **17**, in much the same way as the pillow block forming bearing **5** defined one end of the pivotal axis **9** in the previously-discussed embodiment. As will be explained below, bearing segments **21** and **22**, securely attach engine **14** to the vehicle frame **23**, as best shown in FIG. 2(b).

Referring to FIGS. 3, 3(a), and 3(e), bearing segment **21** comprises an engine component **21(a)** attached to the engine **14** by bolts **26**. Bearing segment **21** further comprises a frame component **21(b)** attached to the automobile frame **23** by bolt **24**. Engine component **21(a)** has an elongated upper track **28** formed with inner track surface **31** and outer track surface **30**. Inner track surface **31** and outer track surface **30** are parallel to each other. Pin **28(a)**, passing through the upper track **28**, is rotationally

mounted within the frame component **21(b)** by means of roller bearings **28(b)** and **28(c)**. Similarly, engine component **21(a)** has an elongated lower track **29** formed with inner track surface **31(a)** and outer track surface **30(a)**. Inner track surface **31(a)** and outer track surface **30(a)** are parallel to each other. Pin **29(a)**, passing through the lower track **29**, is rotationally mounted within the frame component **21(b)** with roller bearings **29(b)** and **29(c)**, the pin and track thus forming surfaces of relative rotation, as above described.

Pin **28(a)** is retained within the frame component **21(b)** by disk **28(d)**, disk **28(e)**, bearing **28(f)**, bearing **28(g)**, screw **40**, screw **41**, screw **42**, and screw **43**. Similarly, pin **29(a)** is retained within the frame component **21(b)** by disk **29(d)**, disk **29(e)**, bearing **29(f)**, bearing **29(g)**, screw **40(a)**, screw **41(a)**, screw **42(a)**, and screw **43(a)**.

Load sensor **48** is retained within bore **47** formed in the frame component **21(b)** by snap ring **49** and snap ring **50**. Pin **51** is press fitted within load sensor **48** and closely fitted within slot **52** of the frame component **21(b)** to assure angular alignment of the sensor **48** with the frame component **21(b)**. The load sensor **48** has a reduced intermediate diameter **53** with a bump **54**. The load sensor **48** is equipped with strain gages **55** connected by wire **56** for remote electrical measurement of transducer signals resulting from loads applied to the bump **54**. The stop screw **57** threadedly engages the frame component **21(b)** and is locked in place by nut **58** with a small gap **59** between the stop screw **57** and the engine component **21(a)**. In any case, the load sensor may be replaced for repair without disturbing retention of the engine to the frame.

Shaft **60** is closely fitted to engine component **21(a)** within bore **61** on one end and supported on the other end by ring **62** which is closely fitted in bore **63** of the engine component **21(a)**. The plate **64** is threadedly secured by screw **65** and screw **66** to the

engine component **21(a)** and retains the shaft **60** within engine component **21(a)**. The tire **67**, which rides radially on needle bearings **68** and rides axially on thrust bearing **69** and thrust bearing **70**, is fixed longitudinally and free to rotate within engine component **21(a)** about shaft **60**. The bore **63** and the outer diameter of the tire **67** exceed the width of the engine component **21(a)** in the middle section **71** in vicinity of the tire **67**. Thus, the tire **67** is exposed for rolling engagement with the frame component **21(b)** on surface **72** and surface **73** and will prevent the engine component **21(a)** from rubbing on frame component **21(b)** when loads are applied along the pivotal axis **17**.

Referring to FIGS. 3(d), 3(e), and 2(b), it can be seen that the engine component **21(a)** is free to roll on pin **28(a)** and pin **29(a)** along the track surface **31** and track surface **31(a)** about a pivotal point **20** located on the pivotal axis **17**. Pivotal point **20** is located at the intersection of lines of projection **74** and **75**. Line of projection **74** extends from the center of pin **28(a)** through the contact point of pin **28(a)** on track surface **31**, in a plane perpendicular to the pivotal axis **17**. Similarly, line of projection **75** extends from the center of the pin **29(a)** through the contact point of pin **29(a)** on track surface **31(a)**, in a plane perpendicular to the pivotal axis **17**.

The range of rotational motion of the engine **14** is limited to the small gap **59** between engine component **21(a)** and stop screw **57**. Arcuate motion of the engine component **21(a)** is limited in one direction by the load sensor **48**, mounted in the bore **47** of the frame component **21(b)** which is attached to the frame **23** with bolt **24**. The force of the engine component **21(a)**, as a result of torque reaction to engine **14** torque delivered to the output shaft **18**, bearing on the bump **54** on the load sensor **48**, deflects the load sensor **48** causing a detectable change in output of the load sensor **48**

proportional to engine **14** torque. Arcuate motion, caused by opposite engine torque from that described above, of the engine component **21(a)** is limited by the stop screw **57** threadedly engaged in the frame component **21(b)** which is attached to the frame **23** with bolt **24**. This motion will not load the load sensor **48** or create a detectable change in output. Thus, it will be understood that the transducer includes parts connected by engine and frame components **21(a)** and **21(b)** to the engine and frame, respectively.

FIG. 4 is an enlarged view of the bearing segment **22** shown in FIG. 2(a) with section lines to define the cross-sectional view of FIGS. 4(a), 4(b), and 4(c). FIG. 4(d) is a cross-sectional view of bearing segment **22** taken along the section lines defined in FIG. 4(a). Referring to FIGS. 4 and 2(a), bearing segment **22** comprises a engine component **22(a)** attached to the engine **14** by bolts **27**. Bearing segment **22** further comprises a frame component **22(b)** attached to the automobile frame **23** by bolt **25**.

Referring to FIGS. 4(b), 4(d), and 2(b), engine component **22(a)** has an elongated upper track **34** formed with inner track surface **36** and outer track surface **37**. Inner track surface **36** and outer track surface **37** are parallel to each other. Passing through the upper track **34** is pin **34(a)** rotationally mounted within the frame component **22(b)** by means of roller bearings **34(b)** and **34(c)**. Similarly, the engine component **22(a)** has an elongated lower track **35** formed with inner track surface **36(a)** and outer track surface **37(a)**. Inner track surface **36(a)** and outer track surface **37(a)** are parallel to each other. Passing through the lower track **35** is pin **35(a)** rotationally mounted within the frame component **22(b)** with roller bearings **35(b)** and **35(c)**.

Referring to FIGS. 4 and 4(b), pin **34(a)** is retained within the frame component **22(b)** by disk **34(d)**, disk **34(e)**, bearing **34(f)**, bearing **34(g)**, screw **76**, screw **77**, screw

78, and screw **79**. Similarly, pin **35(a)** is retained within the frame component **22(b)** by disk **35(d)**, disk **35(e)**, bearing **35(f)**, bearing **35(g)**, screw **80**, screw **81**, screw **82** and screw **83**.

Referring to FIGS. 2, 4, 4(b), and 4(d), shaft **84** is closely fitted to engine component **22(a)** within bore **85** on one end and supported on the other end by ring **86** which is closely fitted in bore **87** of the engine component **22(a)**. The plate **88** is threadedly secured by screw **89** and screw **90** to the engine component **22(a)** and retains the shaft **84** within engine component **22(a)**. The tire **91** riding radially on needle bearings **92** and riding axially on thrust bearing **93** and thrust bearing **94** is fixed longitudinally and free to rotate within engine segment **22(a)** about shaft **84**. The bore **87** and the outer diameter of the tire **91** exceed the width of the engine component **22(a)** in the middle section **97** in vicinity of the tire **91**. Thus, the tire **91** is exposed for rolling engagement with the frame component **22(b)** on surface **93(a)** and surface **94(a)** and will prevent the engine component **22(a)** from rubbing on frame component **22(b)** when loads are applied along the pivotal axis **17**.

Referring to FIGS. 4(d) and 2(b), and from the above discussion, it is apparent that the engine component **22(a)** is free to roll on pin **34(a)** and pin **35(a)** along the track surfaces **36** and **36(a)** about a pivotal point **20** located on pivotal axis **17**. Pivotal point **20** is located at the intersection of lines of projection **95** and **96**. Line of projection **95** extends from the center of pin **34(a)** through the contact point of pin **34(a)** on track surface **36**, in a plane perpendicular to the pivotal axis **17**. Similarly, line of projection **96** extends from the center of the pin **35(a)** through the contact point of pin **35(a)** on track surface **36(a)**, in a plane perpendicular to the pivotal axis **17**. The relative upward and

downward motion between the engine component **22(a)** and the frame component **22(b)** is limited within the bearing segment **21** as discussed above.

More particularly, as shown in FIG. 2(b), bearing segments **21** and **22** are located on the circle indicated at "**C**", and allow the engine **14** to undergo a limited range of rotational movement about the pivotal axis **17**. Thus, as previously described, it can be seen that the **CG** lies within the cone containing the center of the surfaces of relative motion of the compliant engine mount **19** and the circle "**C**". Viewed in this way, it is seen that the bearing segments **21** and **22** effectively replace bearing **4** of the first embodiment shown in FIG. 1.

FIGS. 5, 5(a), and 5(b) disclose a further embodiment of the invention. An engine **175** comprises an internal combustion motor **176** and transmission **177** assembly as might be installed in any common automobile. The engine mounting system according to this embodiment of the invention provides the same separation of engine retention forces from torque force measurement as provided by the previously described embodiments, and is compatible with the three point engine mounting systems widely used by many automobile manufacturers.

FIG. 5 is a side view of the engine **175** having a pivotal axis **178** passing through or near the center of gravity **CG** of the engine **175**. Near the transmission output shaft **179** is a compliant rubber mount **180** which positions one end of the pivotal axis **178**, in much the same way as bearing **5** defined one end of the pivotal axis **9** in the first embodiment discussed herein. Bearing segments **100** and **181**, as will be explained below, securely attach engine **175** to the vehicle frame **123**, shown in FIGS. 5(a) and

5(b), and define the location of pivotal point **182** on the pivotal axis **178** as shown in FIG. 5(b).

Bearing segment **181** is constructed in the same manner as bearing segment **22** described in detail above and shown in FIGS. 4, 4(a), 4(b), 4(c), and 4(d).

Bearing segment **100** shown in FIGS. 6, 6(a), 6(b), 6(c), and 6(d), is an enlarged view of bearing segment **100** shown in FIG. 5, FIG. 5(a) and FIG. 5(b). Bearing segment **100** is capable of measuring engine torque for acceleration and torque of engine braking.

Referring to FIG. 6, bearing segment **100** has a engine component **100(a)** attached to the engine **175** by bolts **126** and a frame component **100(b)** attached to the frame **123** by bolt **124**. As can be seen in FIGS. 6(b) and 6(d), the motor component **100(a)** has an elongated upper track **128** formed with inner track surface **131** and outer track surface **130**. Inner track surface **131** and outer track surface **130** are parallel to each other. Passing through the upper track **128** is pin **128(a)** rotationally mounted within the frame component **100(b)** with roller bearings **128(b)** and **128(c)**. Similarly, the engine component **100(a)** has an elongated lower track **129** formed with inner track surface **131(a)** and outer track surface **130(a)**. Inner track surface **131(a)** and outer track surface **130(a)** are parallel to each other. Passing through the lower track **129** is pin **129(a)** rotationally mounted within the frame component **100(b)** with roller bearings **129(b)** and **129(c)**.

Referring to FIGS. 6 and 6(b), pin **128(a)** is retained within the frame component **100(b)** by disk **128(d)**, disk **128(e)**, bearing **128(f)**, bearing **128(g)**, screw **140**, screw **141**, screw **142** and screw **143**. Similarly, pin **129(a)** is retained within the frame component

100(b) by disk **129(d)**, disk **129(e)**, bearing **129(f)**, bearing **129(g)**, screw **140(a)**, screw **141(a)**, screw **142(a)** and screw **143(a)**.

Referring to FIGS. 6, 6(a), 6(b), 6(c), and 6(d), load sensor **148** is retained within bore **147** formed in the frame component **100(b)** by snap ring **149** and snap ring **150**. Pin **151** is press fitted within load sensor **148** and closely fitted within slot **152** of the frame component **100(b)** to assure angular alignment of the sensor **148** with the frame component **100(b)**. The load sensor **148** has a reduced diameter **153** and reduced diameter **153(a)** with a bump **154** and bump **154(a)**. The load sensor **148** is equipped with strain gages **155** connected by wire **156** for remote electrical measurement of transducer signals resulting from loads applied to either bump **154** or bump **154(a)**. There is a small gap **159** between engine component **100(a)** and bump **154** on the load sensor **148**.

Referring to FIGS. 5, 6, 6(b), and 6(d), shaft **160** is closely fitted to engine component **100(a)** within bore **161** on one end and supported on the other end by ring **162** which is closely fitted in bore **163** of the engine component **100(a)**. The plate **164** is threadedly secured by screw **165** and screw **166** to the engine component **100(a)** and retains the shaft **160** within engine component **100(a)**. The tire **167** riding radially on needle bearings **168** and riding axially on thrust bearing **169** and thrust bearing **170** is fixed longitudinally and free to rotate within engine segment **100(a)** about shaft **160**. The bore **163** and the outer diameter of the tire **167** exceed the width of the engine component **100(a)** in the middle section **171** in vicinity of the tire **167**. Thus, the tire **167** is exposed for rolling engagement with the frame component **100(b)** on surface **172** and surface **173**

and will prevent the engine component **100(a)** from rubbing on frame component **100(b)** when load is applied along the pivotal axis **178**.

Referring to FIGS. 6(d), 6(b) and the above discussion, it can be seen that the engine component **100(a)** is free to roll on pin **128(a)** and pin **129(a)** along the track surfaces **131** and **131(a)** as described above in connection with bearing segment **21**. The rolling distance is limited to the small gap **159**. Arcuate motion of the engine component **100(a)** is limited by the load sensor **148**, mounted in the bore **147** of the frame component **100(b)** which is attached to the frame **123** with bolt **124**. The force of the engine component **100(a)**, as a result of torque reaction to engine **175** torque delivered to the output shaft **179**, bearing on the bump **154** on the load sensor **148**, deflects the load sensor **148** causing a detectable change in output of the load sensor **148** proportional to engine **175** torque. Arcuate motion in the opposite direction of the engine component **100(a)** is also limited by the load sensor **148**, mounted in the bore **147** of the frame component **100(b)**, which is attached to the frame **123** with bolt **124**. This force of the engine component **100(a)**, as a result of engine **175** braking torque delivered to the output shaft **179**, bearing on the bump **154(a)** on the load sensor **148**, deflects the load sensor **148** causing a detectable negative change in output of the load sensor **148** proportional to engine **175** torque.

More particularly, as shown in FIG. 5(b), bearing segments **100** and **181** are located on the circle indicated at "**C**" and allow the engine **175** to undergo a limited range of rotational movement about the pivotal axis **178**. In this embodiment, it can be seen that the **CG** lies within the cone containing the center of the surfaces of relative motion of

the compliant engine mount **180** and the circle "**C**". Again it is seen that bearing segments **100** and **181** effectively replace bearing **4** in FIG. 1.

FIGS. 7, 7(a), and 7(b) disclose still another embodiment of the invention, wherein an engine **200** comprises an internal combustion motor **201** and transmission **202** assembly as might be installed in any common automobile. The engine mounting system according to this embodiment of the invention provides the same separation of engine retention forces from torque force measurement as provided by the previously described embodiments. As mentioned above, this embodiment is also compatible with the three point engine mounting systems widely used by many automobile manufacturers.

Referring to FIG. 7(a), a rear view is shown of an engine **200**, attached to an automobile frame **203**. Bearing segment **204** is attached to the engine **200** by bolts **205** and bolt **206**, and to the frame **203** by bolt **207** and bolt **208**. Bearing segment **209** is attached to the engine **200** by bolts **210** and bolt **211**, and to the frame **203** by bolt **212** and bolt **213**.

This embodiment of the invention is similar to the prior embodiment discussed above, except that a different and simplified construction of the bearing segments is possible due to the plurality of bolts connecting each of the two bearing segments to the automobile frame. This embodiment is an adaptation that is compatible with three point mounting systems where attachment to the frame is more secure than the single bolt disclosed by Etchells in U.S. Pat. No. 2,953,336.

FIG. 7 is a side view of an engine **200** having a pivotal axis **214** passing through or near the center of gravity **CG** of the engine **200**. Near the transmission output shaft **215** is a compliant rubber mount **216** which acts as a bearing to position one end of the

pivotal axis **214**, in much the same way as bearing **5** defined one end of the pivotal axis **9** in the first embodiment discussed herein. Bearing segments **209** and **204**, as will be explained below, securely attach engine **200** to the vehicle frame **203**, shown in FIGS. 7(a) and 7(b), and define the location of pivotal point **217** on the pivotal axis **214**, as shown in FIG. 7(b).

Referring to FIGS. 8, 8(a), 8(b), 8(c), 8(d), 8(e), 7(a), and 7(b), bearing segment **209** comprises an engine component **209(a)** attached to the engine **200** by bolt **210,** bolt **210(a)**, and bolt **211**. Bearing segment **209** further comprises a frame component **209(b)** attached to the automobile frame **203** by bolt **212**, bolt **212(a)**, bolt **213**, and bolt **213(a)**.

Referring to FIGS. 8(c), 8(b), 8(d), 8(e), and 7(b), engine component **209(a)** has a track **218** formed by first track surface **219** and second track surface **220**. First track surface **219** and second track surface **220** are parallel to each other. Within track **218** is a track roller assembly **222** comprising a tire **222(a)**, needle bearings **222(b)**, inner race **222(c)**, washer **222(d)** and washer **222(e)**.

Referring to FIGS. 8, 8(b), 8(d), 8(e), and 7(b), the track roller assembly **222** is secured to the frame component **209(b)** by pin **221** pressed into bore **223**. Frame component **209(b)** has a track **224** formed by first track surface **225** and second track surface **226**. First track surface **225** and second track surface **226** are parallel to each other. Within track **224** is a track roller assembly **227** composed of a tire **227(a)**, needle bearings **227(b)**, inner race **227(c)**, washer **227(d)** and washer **227(e)**. Track roller assemblies **222** and **227** may be commercially available units such as airframe needle roller bearing No. 8812022Y manufactured by the Torrington Company.

Referring to FIGS. 8, 8(a), 8(b), 8(d), 8(e), and 7(b), the track roller assembly **227** is secured to the engine component **209(a)** by bolt **211** passing through the bore **228** in the engine component **209(a)** through the washer **243** and through the track roller assembly **227** and into threaded engagement with the engine **200**.

Load sensor **229** is retained within bore **230** formed in the frame component **209(b)** by snap ring **231** and snap ring **232**. Pin **233** is press fitted within load sensor **229** and closely fitted within slot **234** of the frame component **209(b)** to assure angular alignment of the load sensor **229** with the frame component **209(b)**. The load sensor **229** has a reduced intermediate diameter **235** with a bump **236**. The load sensor **229** is equipped with strain gages **237** connected by wire **238** for remote electrical measurement of transducer signals resulting from loads applied to the bump **236**. The stop screw **239** is threadedly engaged to the frame component **209(b)** and locked in place by nut **240** with a small gap **241** between the stop screw **239** and the engine component **209(a)**.

Thus, the tire **227(a)** is exposed for rolling engagement with the frame component **209(b)** on track surface **226** and track surface **225** and will prevent the engine component **209(a)** from rubbing on frame component **209(b)** when loads are applied along the pivotal axis **214**.

The engine component **209(a)** is free to roll on track roller assembly **222** along the track surface **219** or track surface **220** depending on gravity or vehicle dynamics. First projection line **242** extends from the center of pin **221** through the contact point of track roller assembly **222** on track surface **219**. The significance of first projection line **242** will be explained below. The rolling distance is limited to the small gap **241**.

Arcuate motion of the engine component **209(a)** is limited by the load sensor **229**, mounted in the bore **230** of the frame component **209(b)** which is attached to the frame **203** with bolt **212,** bolt **212(a),** bolt **213**, and bolt **213(a)**. The force of the engine component **209(a)**, as a result of torque reaction to engine **200** torque delivered to the output shaft **215**, bearing on the bump **236** on the load sensor **229**, deflects the load sensor **229** causing a detectable change in output of the load sensor **229** proportional to engine torque. Arcuate motion, caused by opposite engine torque from that described above, of the engine component **209(a)** is limited by the stop screw **239** threadedly engaged in the frame component **209(b)** which is attached to the frame **203** with bolt **212,** bolt **212(a),** bolt **213** and bolt **213(a)**. This motion will not load the load sensor **229** or create a detectable change in output.

FIG. 9 is an enlarged view of bearing segment **204** shown in FIG. 7(a) with section lines to define the cross-sectional views of FIGS. 9(a), 9(b), and 9(c). FIG. 9(d) is a cross-sectional view of bearing segment **204** taken along the section lines defined in FIG. 9(a).

Referring to FIGS. 9, 9(a), 9(b), 9(c), 9(d), 7(a), and 7(b), bearing segment **204** comprises an engine component **204(a)** attached to the engine **200** by bolt **205**, bolt **205(a)**, and bolt **206**. Bearing segment **204** further comprises a frame component **204(b)** attached to the frame **203** by bolt **207**, bolt **207(a)**, bolt **208**, and bolt **208(a)**. The engine component **204(a)** has a track **318** formed by first track surface **319** and second track surface **320**. First track surface **319** and second track surface **320** are parallel to each other. Within track **318** is a track roller assembly **322** composed of a tire **322(a)**, needle bearings **322(b)**, inner race **322(c)**, washer **322(d)** and washer **322(e)**. The track roller

assembly **322** is secured to the frame component **204(b)** by pin **321** pressed into bore **323**.

The frame component **204(b)** comprises a track **324** formed by first track surface **325** and second track surface **326**. First track surface **325** and second track surface **326** are parallel to each other. Within track **324** is a track roller assembly **327** composed of a tire **327(a)**, needle bearings **327(b)**, inner race **327(c)**, washer **327(d)** and washer **327(e)**. Track roller assemblies **322** and **327** may be commercially available units such as airframe needle roller bearing No. 8NBL2022YJ manufactured by the Torrington Company, aforementioned.

Referring to FIGS. 9, 9(a), 9(b), 9(d), and 7(b), the track roller assembly **327** is secured to the engine component **204(a)** by bolt **206** passing through the bore **328** in the engine component **204(a)** and through the track roller assembly **327** and into threaded engagement with the engine **200**.

Referring to FIGS. 7, 7(a), 7(b), 9, 9(a), 9(b), 9(d), tire **327** is exposed for rolling engagement with the frame component **204(b)** on first track surface **326** and second track surface **325** and will prevent the engine component **204(a)** from rubbing on frame component **204(b)** when loads are applied along the pivotal axis **214**.

Engine component **204(a)** is free to roll on track roller assembly **322** along the first track surface **319** or second track surface **320** depending on gravity or vehicle dynamics. The rolling distance is limited in one direction to the small gap **241** previously described in connection with first bearing segment **209**. Motion of the engine component **204(a)** is limited in the other direction by the load sensor **229** previously described in connection with bearing segment **209**.

Second projection line **342** extends from the center of pin **321** through the contact point of track roller assembly **322** on track surface **319**. The intersection of second projection line **342** with the previously described first projection line **242** locates a pivotal point **217** that along with the compliant rubber mount **216** defines the pivotal axis **214**.

More particularly, as shown in FIG. 7(b), bearing segments **209** and **204** are located on the circle indicated at "**C**" and allow the engine **200** to undergo a limited range of rotational movement about pivotal axis **214**. In this embodiment, it can be seen that the **CG** lies within the cone containing the center of the surfaces of relative motion of the compliant engine mount **216** and the circle "**C**". Again it is seen that the bearing segments **209** and **204** effectively replace bearing **4** of the first embodiment shown in FIG. 1.

Various basics of the invention have been explained herein. Details for the implementation thereof can be added by those with ordinary skill in the art. Various combinations and permutations of all elements or applications can be created and presented. All can be done to optimize performance in a specific application. Those skilled in the art will readily appreciate such variations hereof without departing from the spirit and scope of the present invention.